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Positioning new seaweed derived fibre ingredients

# Scope

The aim of this report is to provide the necessary base line information for positioning a new seaweed derived fibre ingredient in the market. As far as we know, there are currently two seaweed derived fibres that are commercially available:

* phytaFIBER® (Java Biocolloid, Indonesia/Italy) is marketed as a 2-in-1 texturizer and dietary fibre made from 100% pure, pulverized *Gracilaria verrucosa*.
* Fibersea® R84. (Olmix, France) is marketed as a clean label, algal based solution for texture and structure. It claims to be a blend of vegetable and marine algae (brown seaweeds).

Note: other products that target specific health benefits and/or bioactivities are available but are not covered here.

The MINERVA seaweed fibres will be positioned (primarily) as new food texture ingredients. Therefore, this report provides some general background on the food fibre/food texture sectors and more specific information that relates to building a technical sales story for a new seaweed fibre ingredient as follows:

Competitive landscape

* Range and type of products in the marketplace, key trend & drivers.
* What the industry is looking for re. new fibre ingredients
* Detail on selected comparator products with a view to establishing suitable benchmarks for seaweed derived products

End use application

* Key application areas for fibres in general
* Likely applications for seaweed derived fibres

Building a specification – what information is needed

* Technical parameters
* Safety & quality parameters
* Labelling

Note: This report makes reference to prototype seaweed fibres that have been developed by and evaluated by CyberColloids Ltd.

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# 1. General context

This section provides some general definitions and context on fibre: what are fibre ingredients, how are they made, what are they used for and importantly - what the industry is looking for re. new fibre ingredients.

* Fibre ingredients have traditionally been added to food as cheap bulking and binding agents, for dietary fibre enhancement and in some cases for other physiological benefit. These fibre ingredients are typically referred to as **standard fibres**. Nowadays, more sophisticated products that bring textural functionality are in the marketplace, these are typically referred to as **functionalised fibres** (sometimes also referred to as highly functional fibres). For the purposes of this report the terms standard and functionalised will be used.
* Note: the term “functional fibre” was/is traditionally used in reference to the physiological functionality/benefit of dietary fibre but has become somewhat confused in the industry literature with the emergence of new functionalised fibres. For the purposes of this report, any reference to physiological function will be clearly stated.
* Fibres are obtained from vegetables (*e.g.* carrot, potato, sugar beet), fruits (*e.g.* apple, citrus), cereals (*e.g.* oat, wheat), pulses & seeds (*e.g.* pea, soy, flax seed), seaweeds. Often from the by-products and waste streams of other food processing activities e.g. fruit pomace, cereal husks and brans. Some comprise the cellulose fraction of plant materials that are not used as foods e.g. wood pulp, bamboo, cotton seed.
* Fibres contain variable amounts of insoluble (e.g. cellulose, hemicellulose & lignin) and soluble (e.g. pectins, glucans, gums & mucilages) carbohydrate fractions depending on the level and type of processing involved in their manufacture and on raw material source.
* Note: the terms “soluble” and “insoluble” are also traditionally used to refer to the physiological functionality of dietary fibre and indeed, the fibre market is still segmented into these two groups. Most market intelligence refers to “insoluble” and “soluble” fibres.
* As the primary focus of this report is on the potential to produce new fibres with technical (textural) functionality the terms soluble and insoluble will be used to define the physical properties of the carbohydrate components and any reference to physiological or dietary functionality will be clearly differentiated.
* The relative proportions of insoluble and soluble carbohydrate components and the presence of other compounds (e.g. proteins) determine the inherent functional properties of any fibre and these vary with raw material source. Fibre components also vary with plant type, part of the plant from which they are derived e.g. peel, pith, bran, husk and when waste streams or by-products are the source material, then it is possible that any pre-processing steps may have modified the intrinsic properties of the final fibre.
* There are many standard fibre products in the marketplace, far fewer functionalised fibres (See section 2.4) but there is certainly scope and demand for more and different fibres that offer formulators interesting tools to meet current consumer & industry demands.
* Functionalised fibres with technical properties that rival those of the classic food texture additives *e.g.* hydrocolloids, stabilisers, emulsifiers are particularly sought as functionalised fibres are considered to be food ingredients, not food additives and thus do not fall under the same regulatory constraints as additives (see Appendix 1). Many are therefore considered as clean label alternatives to traditional food additives.

## 1.1. Textural functionality – what is industry looking for?

* From a texture perspective, fibre **functionality essentially stems from a capacity to hold or bind water and sometimes fat**, which in turn provides viscosity and texture.
* Standard fibres typically offer limited technical functionality whereas functionalised fibre products that are in the market show significant water binding capacity and also give viscosity and gelling behaviour that until recently, has only been provided by hydrocolloids.
* Some of the cellulose derived fibres also exhibit fat mimetic properties that are comparable with texture additives such as Microcrystalline Cellulose (MCC). When used with high shear, they form semi-gel structures with many of the sensory attributes of fat e.g. creaminess, mouthfeel-fatty coating and even a smooth and glossy appearance.
* A number of products are also marketed on the basis of emulsification properties and the potential for full or partial replacement of natural (e.g. egg) and additive emulsifiers.
* Note: some fibre products can be used in application/food manufacture without any pre-activation (generally high shear) processing to fully disperse and hydrate the fibres whereas others require high shear to be fully functionalised in application.

### Water binding capacity

* Water binding capacity (WBC) is quantified in g/g terms i.e. weight of water bound per gram of fibre ingredient. Note: different methods are used by industry to quantify WBC and “water holding capacity” is sometimes reported – this can make it difficult to compare the functionality of different fibres, but all data presented here is derived from the same standard method so that results are comparable.
* **Standard fibres** are generally considered to have a WBC within **2-10g/g.**
* **Functionalised fibres** derived from similar sources have much higher WBC – **10-30g/g**.
* **Commercially available seaweed fibres** typically have a WBC in the range **5-6 g/g.**
* **Prototype activated fibres** with a WBC of **10-18g/g** have been produced by CyberColloids Ltd.
* Figure 1.1. shows a range of WBC for different commercially available and prototype fibres. Those at the higher end are considered functionalised, many more products exist at the lower end of the range.

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| Figure 1.1. Water binding capacity (g water/g fibre) of a range of fibres, including commercially available and experimental seaweed fibres (in brown). |
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* Table 1.1. below gives a comparison of WBC between standard and functionalised fibres from similar resources.
* Note: the insoluble:soluble fibre component of seaweed and water binding potential will be determined by the methodology used to produce the fibre *i.e.* what components are present and whether any “activation” of key components is carried out.

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| Table 1.1. Water binding capacity of functionalised vs. standard fibres. | | |
|  | **g bound water/g of fibre** | |
| Fibre | **Standard fibres** | **Functionalised fibres** |
| High % insoluble component | | |
| Cellulose (wood, bamboo, cotton) | 2-5 | 25-30 |
| Wheat | 2-3 | <5 |
| Mostly insoluble with % of soluble components | | |
| Oat | 2-3 | <7 |
| Mix of insoluble and soluble components | | |
| Citrus (NB: mixed sources) | 5-10 | 8-20 |
| Apple | 3-7 | <15 |
| Carrot | <9 | 11-14 |
| NB: compiled from CyberColloids Ltd own data. | | |

### Fat mimetic properties

* Functionalised food fibres can be viewed as carbohydrate fat replacers and the majority of commercially available products are marketed on the basis of some fat replacement potential (across a wide range of applications).
* Some can be considered true fat mimetics in that they can be used to imitate both the organoleptic and physical properties of fats and oils. Functionalised cellulose rich fibres, in particular, have good fat mimetic properties. They form highly viscous, shear-thinning gels that resemble fat in bulk and appearance but also in organoleptic quality.
* Example: fat reduced mayonnaises. Full fat mayonnaise typically contains 80% fat whereas reduced fat equivalents typically contain 3-30%. There is a requirement to replace and structure upwards of 70% water and this can be achieved with the addition of <1.5% functionalised cellulose & citrus fibres.
* **Seaweed based fibre product Fibersea®** R84 (Olmix, France) is **marketed on the basis of fat reduction properties.**

### Viscosity & gelling behaviour

* Whether purposefully “activated” or made more available through processing, various components from fruit and vegetable fibres in particular, can deliver additional gelling and thickening functionality that has to date only been provided by hydrocolloids.
* Many functionalised fibre products are marketed on the basis of hydrocolloid replacement but gelling functionality, in particular, is in demand.
* **Seaweed based fibre phytaFIBER®** (Java Biocolloid, Indonesia/Italy) is derived from the red seaweed *Gracilaria* and has the basic textural functionality of agar. It is **marketed on the basis of its gelling properties.**
* Edge Ingredients, USA is promoting close/new to market **citrus and vegetable fibres** (FiberColloidsTM) that all have **gelling functionality** associated with the pectin content**.**
* Note: it is difficult to compare gelling functionality between different products in that the target components and gelling mechanism varies between different sources.
* For the MINERVA fibres, it will be necessary to benchmark gelling & viscosity against other fibres but also against commercial alginates (primarily sodium alginate) – potential targets for replacement.
* Note: commercially available sodium alginates are optimised to target a wide range of gel strengths and viscosities. Alginates derived from different seaweeds (or blends) have different properties *e.g.* M:G ratio & molecular weight so it is necessary to evaluate new fibres against a range of comparators.
* A basic summary of gel strength[[1]](#footnote-1) and viscosity[[2]](#footnote-2) for commercial sodium alginates and prototype seaweed fibres (evaluated at CyberColloids Ltd) is given in Table 1.2 below.

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| Table 1.2. Gel strength and viscosity properties of seaweed fibres *c.f.* commercial controls | | |
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| Sample | **Gel strength (g)** | **Viscosity at 1%** |
|  | **Break point** | **(mPa. S)** |
| Typical range for commercial products | (100-) 300-800 (-1000) | (100-) 300-600 (-1000) |
| Prototype seaweed fibres | 100-430 | 650-1300 |

* Different prototype seaweed fibres that have been evaluated at CyberColloids Ltd have shown commercially interesting/relative properties:
* viscosities that tend towards the higher end of the range of commercially useful alginates;
* gel strengths that fall within the range of commercially useful alginates, albeit at the lower end but note that these are not pure alginate products.
* Prototype fibres have been successfully formulated into different restructured food models at CyberColloids Ltd as gelling agents to replace sodium alginate (See Section 3.2).

## 1.2. How is functionality improved in functionalised fibres?

* Functionalised fibres that are currently in the market are produced using chemical, enzymatic, mechanical (shearing and microfibrillation), thermal or thermo-mechanical (extrusion) treatments (Table 1.3).
* These processes variably affect key properties such as solubility, particle size, fibre length and molecular weight.
* Processing is generally aimed at the manipulation or activation of certain components within the fibre. In particular:
* separation and/or functionalisation of the cellulose fraction to improve water binding;
* the concentration and/or functionalisation of soluble fractions e.g. pectins to provide additional water binding but also more interestingly, to promote gelling capacity.
* We do not know if any particular processing techniques are applied to the currently available seaweed fibres to promote functionality, beyond controlling milling.
* Potential strategies for functionalising the fibre components of brown seaweed could include:
* functionalisation of the cellulose fraction to improve water binding;
* activation of the gelling functionality of the alginate (*in situ).*

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| Table 1.3: Some examples of fibres and possibilities for functionalisation | | |
|  | **Source** | **Functionalisation** |
| Mostly insoluble components | | |
| Powdered cellulose and cellulose rich fibres extracted or isolated from non-food plant materials | Wood | **Focus:** improving the water binding capacity of cellulose  Milling to improve surface area  Processing to “open-up” cellulose structure  Microfibrillation of cellulose  Removal of non-cellulose components |
| Cellulose rich fibres extracted or isolated from food processing by-products. May have some soluble components | Pea  Wheat  Oat | **Focus:** improving the water binding capacity of insoluble and soluble fractions (pectins, glucans, gums & mucilages, starches)  Mechanical, chemical & enzymatic treatments to “open-up” the structure.  Removal/concentration of certain fractions. |
| Mix of insoluble and soluble components | | |
| Fibres produced from fruit and vegetable food processing side streams | Apple  Citrus  Carrot  Sugar beet  Potato (non-starch) | **Focus:** functionalising the various components to provide water binding, gelling and viscosity  Mechanical, chemical & enzymatic treatments to “open-up” the structure.  “Activation” of certain soluble fractions e.g. pectins.  Removal/concentration of certain fractions. |
| NB: compiled from AT Consulting own data and from industry contacts. | | |

# 2. Competitive landscape

## 2.1. Market headlines

* Recent headlines from the different market analysis companies that report on food fibre or dietary fibre markets are estimating the **global market** (NB: based on traditional segregation into insoluble and soluble sectors) to be **in the region of US$ 5 to 7 billion** currently but **rising to US$ 9 to 10 billion** in the next 4 to 6 years.
* Note: defining the market size for functionalised fibres is difficult as there is **currently no clear boundary between dietary fibres and functionalised fibres** other than the purpose of use. The terminology is yet to be embedded in the industry.
* The fruit and vegetable fibre sector was reported to account for around 35% of the market share (approaching US$ 2.5 billion) in 2018 and is expected to show strong growth in the next 4 to 6 years
* Note: the coverage and depth of analysis varies significantly between such reports and thus the values reported must be taken as indicative, however, a number of common headlines are apparent:
* the insoluble fibre sector dominates the market in terms of value (US$), currently around 70% of the market share;
* North America is the largest market;
* Asia Pacific (closely followed by Europe) is expected to maintain the highest CAGR over the next period.
* It is generally reported that strong growth in the global fibre market is currently, and will continue to be, driven by:
* health-conscious consumers that are demanding added benefits that go beyond basic nutrition;
* Innovative NPD, in particular in healthy-option foods (e.g. reduced sugar and fat formulations) and functional foods.

## 2.2. Pricing

* Most functionalised fibres have a market value of in the range **€4-10/kg (dry weight)** depending on functionality although **some fall into the €15-20 range**.
* Note: the **current range of functionalised fibres in the market is relatively small** and there is plenty of scope (and demand) for different fibres, from different sources and with better functionality.
* **Gelling fibres in particular are of interest** and there is currently only one gelling fibre made from fruit (close to/new to market) and one from seaweed (phytaFIBER®) in the market.
* **Pricing generally reflects the functionality of the fibre** and higher water binding capacity translates into higher market prices (Fig. 2.1). Note however, that **cost-in-use is a preferable indicator** as more functional products can be used at lower dose rate (and vice versa) however it is difficult to estimate a generic cost-in-use as different applications require different inclusion rates.
* Note that Figure 2.1. below does not include the phytaFIBER® product as it is essentially a gelling fibre and not comparable with most fibres that offer water binding functionality.
* Note also that prices are indicative and will vary depending on quantity and shipping.
* **The indicative price for phytaFIBER® is €19/kg**
* **The indicative price for Fibersea® R84 is €7.40/kg**

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| Figure 2.1. Fibre price generally reflects functionality (WBC in this case) |
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## 2.3. Key trends and drivers

* From a market perspective, the opportunity to develop new food fibre ingredients has never been better. The general concept of utilising plant-based materials, including processing and waste streams, to produce clean label, natural ingredient alternatives to food additives ticks many boxes for consumers and producers alike but also addresses a number of key global issues that are the forefront of research, industry, health and policy making agendas.
* In many cases, functionalised fibres offer a clean label alternative to traditional texture ingredients on account of their improved functionality and more natural/less processed perception.
* From a seaweed perspective - the use of seaweed ingredients in food and for health & wellbeing is becoming more mainstream and there is a clear trend for a significant increase in the number of products being launched outside of the traditional Asian markets, Europe is showing steady growth.
* Creating value and new commercial enterprise from marine algal resources has been a been a key thematic focus for UK & European funded research in recent years. This reflects the wider ambition to valorise aquatic biomass (still considered to be underutilised) for sustainable development within the National and EU bio economy and indeed, building a healthy Blue Economy is recognised as a vital contributor to economic growth and a vehicle for rebuilding and revitalising regional marine economies.
* Table 2.1. below summarises some of the key drivers from different perspectives.

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| Table 2.1. key drivers & opportunities for the development and application of new functionalised fibres. | |
| *Consumer trends* | |
|  | * growing global demand for healthier, less processed foods with simplified labels * increasing trend for plant-based nutrition * increased uptake of vegetarian and vegan diets/lifestyle * increased awareness of impact of food processing on the environment * more demand for “free-from” or “reduced” foods *e.g.* potential allergens, fat, salt, sugar and additives (E numbers in Europe) |
| *Industry benefits* | |
|  | * potential to add value from processing by-products and side streams * reduced waste burden (financial & environmental benefits) * diversification of offerings * potential for wide application in different market sectors * clean label alternatives * opportunity to service lucrative, emerging market sector |
| *Global drivers* | |
|  | * contribution to circular economy * smart/sustainable use of underutilised resources * minimising food loss & waste – addressing food security targets * opportunities for meeting reduction targets (*e.g.* fat & sugar) |

## 2.4. Range and type of products in the marketplace

There are many standard fibres in the marketplace, but this section provides detail on a selection of key products with interesting functionality that can be considered benchmarks for any new market entrants. These have been chosen on the basis of availability and presence in the food industry. Most functionalised fibres are derived from citrus, others from fruit, vegetable, cereal and algal sources but the most highly functional product is derived from wood pulp.

* They are considered to be **technically superior** to most other fibre product offerings.
* However, technical functionality is not the only requirement - one of the **key challenges** in developing more natural, less processed food ingredients is to **achieve an acceptable sensory profile** as both colour and odour can limit application.
* Most of the fibres discussed here have a **neutral sensory profile**, being mostly cream/light tan in colour and odourless however, the apple and sugar beet derived fibres are darker in in colour and the seaweed derived fibres have mild marine odours.
* Table 2.2. below summarises some of the key properties of selected fibres.

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| Table 2.2: summary detail on commercially available functionalised fibres. | | | | | | |
| Product | **Source** | **Fibre contents** | **Suggested application** | **Key properties** | **Recommended dose** | **Label declarations** |
| Fruit fibres | | | | | | |
| Citri-Fi® 100  Fiberstar, USA | Citrus pulp fibre from juicing industry | 70% total fibre  35% soluble  35% insoluble | Bakery, Meat products,  Dairy, Sauces & dressings, Pet food | High WBC, Fat replacement &  fat mimetic, Neutral sensory profile | 0.5-1% | Citrus fibre, Dried orange pulp. Citrus flour, Natural,  Kosher, GRAS, Non-GMO, Non-allergenic, Gluten-free |
| Herbacel® AQ® plus Citrus  Herbafood Ingredients GmbH, Germany | By product of pectin extraction | 88-93% total fibre  75% insoluble  17-20% soluble | Beverages & purées, Bakery, Bakery jams & fillings, Dairy products, Desserts & ice cream, Meat and sausages, Nutritional supplement, Meal replacers, Soups, sauces & spreads, Confectionery | High WBC,  Fat replacement & fat mimetic, Neutral sensory profile. **Requires shear to improve functionality** | 0.5-1% | Citrus fibre, Dietary fibre, Allergen-free, Vegan/vegetarian,  Kosher, Halal |
| Ceamfibre® 7000  Ceamsa, Spain | Citrus peel waste from pectin extraction | 86.5% total fibre of which 85% is insoluble | Meat and sausages, Dressings and sauces, Bakery, Bakery jams & fruit preps, Cheese and yoghurts | Water and oil binding, **Pseudo-emulsification**,  Soy, egg & starch replacement, Fat replacement, Neutral sensory profile | 1-5% | Citrus fibre, Natural, Non-allergenic, Gluten-free, GRAS. |
| Herbacel® AQ® plus Apple  Herbafood Ingredients GmbH, Germany | By product of pectin extraction |  | Meat and (vegan) meat alternatives, Fruit preparations and -fillings, Instant powders, Bread, cakes & pastry products | High WBC, Good stability under processing, **Does not need shear to improve functionality, Darker in colour, Sweet/fruity odour** | 0.5-1% | Citrus fibre, Dietary fibre, Allergen-free,  Vegan/vegetarian, Kosher, Halal |

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| Table 2.2 continued: summary detail on commercially available functionalised fibres. | | | | | | |
| Product | **Source** | **Fibre contents** | **Suggested application** | **Key properties** | **Recommended dose** | **Label declarations** |
| Vegetable fibres | | | | | | |
| ID 809 carrot  ID Foods, France | Whole carrot concentrate | <92% fibre | Not specified by manufacturers | High WBC, thickening & stabilising properties, use in emulsions, excellent cost-performance ratio | Not specified | Carrot fibre, Vegetable fibre, Natural, GMO-free, Gluten-free, Cholesterol-free, Additive free. |
| KaroPro 1-18 & 1-26  Food Solutions Team, Switzerland | Pulp of the carrot juicing industry | 63% insoluble fibre  21% soluble fibre | Processed meats  Bakery  Sauces & dressings  Soups | High WBC, 2 grades produced (I-26 higher WBC), Starch replacement, Neutral colour, slight earthy odour | <2% | Carrot product  Carrot fibre |
| Vidofibres, BF 5  Unipektin, Switzerland | Beet pulp after sugar extraction | 70% total fibre  >52% insoluble  <18% soluble | Bakery  Meat products  Healthy formulations/fibre enhancement | Neutral colour, slight earthy odour | Not specified | Beet fibre, Natural, Clean label, Gluten-free |
| Cereal fibres | | | | | | |
| Vitacel® Oat fibre HF200  J.Rettenmaier & Söhne GmbH (JRS), Germany |  | ≈ 96% dietary fibre  <0.5% is soluble | Bread & bakery, Meat & sausage, Milk & cheese, Extruded & pasta products, Beverages, Fruit preps, Healthy formulation | High water and oil binding, good texture control, Neutral sensory profile |  | Oat fibre, Dietary fibre |
| Cellulose fibres | | | | | | |
| SenseFi® (Borregaard, Norway). | Wood pulp | 93% fibre (cellulose) | Emulsified meat products, Bakery including gluten free and bakery fillings, Mayonnaise & dressings; Spreads, Ice cream & frozen yoghurts. | **Very high WBC (>20 g/g)**, Forms a gel-like structure – **fat mimetic**, Very stable under processing, Neutral sensory profile, **Requires high shear to be fully functionalised.** | 0.3-0.7% | Powdered cellulose or E460, Vegetarian, Halal, Kosher, Non GMO. |

### Commercially available seaweed fibres

* As far as we know, there are currently two seaweed derived fibres in the market (Table 2.3):
* **phytaFIBER ®** (Java Biocolloid, Indonesia/Italy) - marketed as a 2-in-1 texturizer and dietary fibre made from 100% pure, pulverized *Gracilaria verrucosa* (a red seaweed).
* **Fibersea®** **R84** (Olmix, France) marketed as a clean label, algal based solution for texture and structure. It claims to be a blend of vegetable and marine algae (brown seaweeds) fibres.
* Note: Olmix also produce **Emulsea®** which is marketed as an algal based emulsifier with egg and fat replacement properties. It is a blend of marine algae, linseed and vegetable fibre. Recommended application in dressings, sauces and baked goods.
* Data sheets and sales information will be appended to this report.

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| Table 2.3: key properties of commercial seaweed fibres | | |
|  | **phytaFIBER®** | **Fibersea® R84** |
| Source | pulverized *Gracilaria verrucosa,* aqueous extract no chemicals added | Blend of vegetable and brown seaweed |
| Fibre content | 85% dietary fibre  45% water soluble  40% water insoluble | 69% |
| Key functionality from manufacturers recommendations | Gelling  Low temperature solubility (450C) from agar  Thickening  Good mouthfeel  Fibre enrichment | Syneresis control  Stabiliser  Fat reduction  Replacement of potential allergens  Fibre enrichment |
| WBC (standard method) | WBC = 5 g/g | WBC = 5.8 g/g ( |
| Sensory profile (CyberColloids evaluation) | Cream to tan coloured, fine powder  Mild salty/marine odour | Cream to tan coloured, fine powder  Mild marine odour |
|  |  |  |
| Suggested application | Non-dairy milks (soy, almond, oat)  Coffee drinks  Desserts, puddings & yoghurt  Dietetic drinks for elderly | Soups, sauces and dressings  Bakery & pastry  Vegetarian savoury |
| Recommended dose |  | 0.5-4.0%. |
| Label declarations | Gluten-free  GMO-free  Organic  In Europe labelled as seaweed powder or Gracilaria verrucosa powder | Clean label  Vegan  Organic  Allergen free  Non GMO |

# 3. End use application

This section provides some general context for the use of fibres in different food applications and highlights some potential areas where seaweed derived fibres might find application. For the latter it is also important to also consider the potential to replace sodium alginate.

## 3.1. Fibre use in application

Fibres are added to food for a number of reasons (Table 3.1). Traditionally as bulking agents and for dietary fibre enhancement but as more sophisticated products, with improved functionality, have become available, their utility has increased.

Food fibres have wide application across key food industry sectors – depending on type & level of functionality and sensory profile. Seaweed fibres could find application in the following products:

* Bakery including gluten free options;
* Snacks *e.g.* cereal/granola bars, and fruit snacks;
* Processed meat & fish products;
* Plant based, vegan & vegetarian products including analogue products;
* Soups, sauces & dressings;
* Beverages;
* Nutritional foods including meal replacements and dietetic foods.

The following applications more typically require specific technical functionality and/or a neutral sensory profile and are less likely to be suited for application of seaweed fibres:

* Dairy including ice cream and desserts;
* Sweets and confectionery.

In all application sectors there is the potential for clean label and healthy formulations:

* Replacement of traditional food additives *e.g.* hydrocolloids and emulsifiers;
* Free-from alternatives *e.g.* gluten, egg, soya, dairy
* Fat reduction - in particular fat mimetic properties of highly functional fibres;
* Sugar reduction – bulking and natural sweetness of some fruit fibres;
* Protein extension *e.g.* in meat products to allow lower % meat protein;
* Natural flavour and colour - some fibres;
* Added dietary fibre;
* Specific textures for dietetic products;
* Some fibres are marketed on the basis promoting satiety and digestive health.

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| Table 3.1. Key benefits & functionalities of utilising food fibres in different products. | | |
| Bakery | **Water management:**   * binding & stabilizing of free and added water; * reduced evaporative losses during baking and lower bake time; * retarded postproduction staling; * stability during/after freezing; * extended freshness and improved shelf-life; * improved elasticity, volume, leavening & yield; * improve handleability of doughs and pastry during processing and reduce stickiness; * improved production costs; * reduced syneresis in fruit preps and fillings. | **Texture control:**   * increased stability & strengthening to the gluten network; * better crumb properties (softness or elasticity); * reduced crumbling and breakage of pastries and biscuits; * replacement of bread improvers, emulsifiers, starch and other texture agents; * thickening/viscosity in fruit fillings; * prevention of boil out, bake stability in fillings. |
| **Sensory:**   * improved taste and colour; * important in gluten free products which can lack colour and flavour; * some fibres are dark and highly flavoured, can be limiting in some applications; * fruit based fibres can impart natural fruitiness. | **Clean label and healthy formulating:**   * increased fibre content; * improved fermentation tolerance; * replacement (partial or full) of allergens including eggs, gluten; * fat/calorie reduction; * typically used in fibre blends for gluten free products, both soluble and insoluble fibre components are important; * clean label - replacement of traditional food additives. |
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| Snacks | **Cereal/granola/fruit & nut bars:**   * binding & stabilizing of added water giving moistness; * moisture control for better bite in baked products; * dietary fibre enhancement; * clean label - replacement of traditional food additives; * neutral colour and taste not so critical as in other applications; * fruit based fibres can impart natural fruitiness. | **Fruit leathers, dehydrated fruit snacks:**   * stabilization; * minimizing syneresis; * anti-caking agents; * added natural pectin functionality; * clean label - replacement of traditional food additives; * fruit fibres can add natural fruitiness (colour/flavour). |

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| Table 3.1. continued. Key benefits & functionalities of utilising food fibres in different products. | | |
| Processed meat & fish products | **Water management and texture control:**   * binding & stabilizing of free and added water; * reduction of shrinkage, cook-loss and purge; * reduced brine leakage; * improved freeze-thaw stability; * reduction of syneresis; * improved binding in emulsified products. | **Enhanced texture and sensory properties:**   * improved juiciness/succulence; * better bite & texture; * smooth, creamy texture in spreadable meats; * improved spreadability in meat/fish spreads; * excellent texture in fat reduced products. |
| **Improved processing and handleability:**   * better water management for improved yield; * Improved sliceability; * reduction of stickiness; * improved cling of marinades and liquid seasonings. | **Clean label and healthy formulating:**   * fat reduction; * replacement of phosphates; * meat extension, lower meat content; * clean label - replacement of traditional food additives. |
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| Vegan & vegetarian products | **Water management and texture control:**   * binding & stabilizing of free and added water; * reduction of shrinkage, cook-loss and purge; * improved freeze-thaw stability; * reduction of syneresis. | **Enhanced texture and sensory properties:**   * clean label - replacement of traditional food additives; * Improved juiciness; * better cohesiveness. |
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| Soups, sauces & dressings | **Water management and texture control:**   * binding & stabilizing of free and added water; * viscosity and thickening; * decreased syneresis and separation; * improved freeze-thaw stability; * improved cling in sauces & dressings. | **Emulsification & fat replacement:**   * full or partial replacement of traditional emulsifiers; * full or partial replacement of egg; * clean label and healthy formulation; * fat mimetic properties allowing for very low fat products; * improved mouthfeel, creamy, fat like textures; * added gloss & sheen; * clean label - replacement of traditional food additives. |

## 3.2. Typical applications for sodium alginate

* Seaweed derived fibres have the potential for full or partial replacement of sodium alginate in different foods where viscosifying and/or gelling functionality is required.
* Note: sodium alginate also has other important properties - cold solubility, heat and freeze-thaw stability.
* Typical applications for sodium alginate would be: ice cream & sorbet; bakery creams (e.g. cold whip products); dressings & low fat spreads; fruit fillings, preparations & juices; restructured foods (e.g. heat resistant jellies).
* Alginate is used in ice cream as a stabiliser (prevents ice crystal formation, prevents shrinkage and contributes to even and slow meltdown) and for controlled viscosity during processing.
* It is used in desserts and puddings for its viscosifying & gelling ability, cold solubility and cold setting and also freeze thaw stability.
* Note: a neutral sensory profile is essential for the above two applications, however.
* Sodium alginate is commonly used in the production of restructured food products including fruit, vegetable, meat and fish. Obvious examples are red pepper/pimento chunks as used in stuffed olives, onions rings using restructured onion puree and surimi style fish products using restructured fish/shellfish purees.
* The alginate is gelled using calcium ions, usually through an **internal setting method** where the necessary gelling agents incorporated into the formulation with the alginate, gelling is initiated on mixing.
* Or through a **diffusion setting method** where the alginate containing formulation is put into contact with a calcium brine, typically a bath or spray. Gelling is initiated as calcium diffuses through the product.
* Seaweed fibres are likely to be coloured and to have a marine sensory profile – depending on level of processing applied and whether any clean up steps are implemented. Application may be restricted to formulations that can sufficiently mask any negative sensory attributes or that benefit from a marine savoury profile. A number of restructured foods could be suitable:
* **Restructured vegetables:** alginate is used in restructured products as a gelling agent. Being heat stable and easy to form is also beneficial. Onion rings and pimentos (used in stuffed olives etc) are classic examples, both are highly savoury and coloured.
* **Restructured meat & fish products:** alginate is also used to gel restructured meat and fish products like burgers, balls, nuggets (fresh & frozen). Heat and freeze-thaw stability are important properties.
* **Plant based, vegan & vegetarian savoury products:** for reasons already given, alginate can be used to gel plant based savoury products (fresh & frozen).
* The viscosifying properties of seaweed fibres may also be used to control texture in **soups & sauces**. Such products are typically coloured and highly flavoured.

# 4. Building a specification – what information is needed

In order to bring a new fibre ingredient to market, MINERVA will require a product specification for each new ingredient that details important technical, quality and safety parameters.

It will also help to build a technical sales story that gives more specific detail on functionality in application that can be presented to potential buyers.

## 4.1. Product specification

The production and sale of food in Europe falls under General Food Law in that all food in the market must be safe and of sufficient quality. However, there are regional variations that may come into play for certain aspects of food law and some countries require a different level of information/detail to be provided re product specifications and labelling. Some general comments are given below and what CyberColloids understands re. the regulatory situation is given in Appendix 1 at the end of the report but **please confirm with regulatory experts**.

Table 4.1. details the basic information that will be required to build a product specification and some examples of product specifications for commercial products are given in Table 4.2.

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| Table 4.1. Basic information required to build a product specification | |
| Basic information | **Necessary safety information** |
| Product description – including format, source material and comment on intended use  Sensory criteria – appearance, colour, odour  Key properties – *e.g.* water binding, solubility  Nutritional composition – see below  Recommended application (optional)  Recommended dose range (useful, not always given) | Microbiological parameters – see below  Heavy metals – see below  Allergens – see below  Contaminants – see below  Packaging, storage, shelf life  Declaration/labelling – see below |

### Sensory criteria – appearance & organoleptic quality

* For guidance, Figure 4.1. shows some examples of commercially available fibres that are considered to be neutral in colour plus the 2 commercial seaweed fibres.
* Sensory evaluation (including taste) will be carried out as part of planned technical evaluation.

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| Figure 4.1. Examples of commercial products showing colour | | | |
| Carrot fibre | Citrus fibre | phytaFIBER® | Fibersea® R84 |
|  |  |  |  |

### Key properties

* Particle size and water binding capacity advised; other key properties might be determined as part of planned technical evaluation.

### Nutritional composition

* Relevant to product specification and labelling – Group 1 nutrition breakdown is mandatory for labelling - energy, protein, carbohydrate, fat.
* Carbohydrate breakdown expected for a fibre product – at least total fibre + other carbohydrates
* Moisture/water essential for a powdered product
* Ash/total minerals of interest for seaweed products, in particular Na – but K, Ca, Mg, Zn, Fe are important in relation to Na replacement.

### Microbiological parameters

* There is a requirement to show that food is safe to eat - food products must conform to food safety law across the manufacture and sales chain – see <https://ec.europa.eu/food/safety/biosafety/food_hygiene/microbiological_criteria_en> for detail.
* Also that food is microbially stable during storage. Dried, powdered products are generally safe if the moisture content is sufficiently low (rule of thumb <10%) and they are stored correctly (*i.e.* moisture levels do not increase). Accelerated shelf-life studies are typically carried out to establish storage conditions and shelf life.

### Heavy metals & contaminants

* Product will have to conform to regulatory limits (see Appendix 1) but a few points to consider.
* **Iodine & Arsenic** of particular importance and irrespective of regulatory requirements, food companies typically seek as much information as possible regarding these two. In particular the ratio of organic (oAS) to inorganic (iAS) arsenic and whether supply of a seaweed derived product with standardised content is possible (*i.e.* without any seasonal or other variability).
* **Marine allergens –** include fish, crustaceans, molluscs, recommended to check out - <https://www.food.gov.uk/business-guidance/allergen-labelling-for-food-manufacturers>
* Particularly important if a vegetarian or vegan declaration is to be made as no traces of fish, crustaceans, and mollusc should be detected.
* **Marine contaminants –** include dioxins, PCBs & pesticides but note: not all food approved laboratories can analysis for marine contaminants and standard analytical suites may not cover what is needed.
* Raw material specifications should also consider heavy metals & contaminants & may reduce some analytical burden.

### Labelling, packaging & declaration

* EU regulations apply re. providing the [correct information to consumers](https://ec.europa.eu/food/safety/labelling_nutrition/labelling_legislation_en), it is advised that MINERVA works with the regulatory expert to achieve this.

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| Table 4.2. Examples of a product specifications, left = seaweed fibre, right = carrot fibre. | |
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## 4.2. Technical sales story

* Companies looking to utilise new ingredients will likely ask for a technical sales pitch that demonstrates the potential utility of the ingredient.
* Note: not all food companies have their own R&D or food applications capability and will be looking for as much information as possible re. re-formulation with new ingredients and/or developing new products.
* Technical literature generally takes the form of a dossier of key properties and functionalities (with much more detail than provided in the product specification) or example recipes/formulations.
* Below are a series of links to examples of manufacturers literature that illustrate the kind of information that MINERVA could present – pending evaluation of the fibres.
* Overview of texture potential for [Sensefi®](https://www.sensefi.com/content/download/108764/19579327/file/PB-SF-01-EN%20-%20SenseFi%20Product%20Brochure.pdf) cellulose fibre and example of an [application in meat](https://www.sensefi.com/content/download/108413/19525242/file/AB-EM-01%20-%20SenseFi%20in%20Emulsified%20Meat%20(sausages).pdf).
* Application focussed [brochures from Herbafoods](https://www.herbafood.de/en/portfolio-item/brochures/) for citrus and apple fibre.
* Both above are well established products with many years of R&D behind them, the level of information provided with some of the newer ingredients is not so comprehensive
* Food Solutions Team, Switzerland have a range of [test formulations](https://www.foodsolutionsteam.com/en/backwaren/) available for use with their vegetable fibres.
* Unipektin, provide very basic [formulation guides](https://unipektin.ch/wp-content/uploads/DataSheets/ApplicationSheet_VIDOGUM_KX22_F001_Ketchup_20140721.pdf) for their various products.

# Appendix 1: what we understand re. regulatory

## Dietary fibre

The EU, [regulation 1169/20111](http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011R1169&from=EN) defines fibre as “ carbohydrate polymers with three or more monomeric units, which are neither digested nor absorbed in the human small intestine and belong to the following categories: (i) edible carbohydrate polymers naturally occurring in the food as consumed; (ii) edible carbohydrate polymers which have been obtained from food raw material by physical, enzymatic or chemical means and which have a beneficial physiological effect demonstrated by generally accepted scientific evidence; (iii) edible synthetic carbohydrate polymers which have a beneficial physiological effect demonstrated by generally accepted scientific evidence”'.

The [United States Food and Drug Administration](https://www.regulations.gov/contentStreamer?documentId=FDA-2012-N-1210-0875&contentType=pdf) (FDA) definition refers to “non-digestible soluble and insoluble carbohydrates (with 3 or more monomeric units), and lignin that are intrinsic and intact in plants; isolated or synthetic non-digestible carbohydrates (with 3 or more monomeric units) determined by FDA to have physiological effects that are beneficial to human health”.

Both differ slightly from the [Codex Alimentarius](http://www.codexalimentarius.net/download/report/710/al32_26e.pdf) which specifies 10 or more monomeric units and leaves the decision on whether to include 3-9 monomers to national authorities. Dietary fibre is also referred to as Non-starch polysaccharides (NSP), commonly by [the Food and Agriculture Organization](https://ec.europa.eu/jrc/en/health-knowledge-gateway/promotion-prevention/nutrition/fibre#_FAO2009) (FAO) of the United Nations and the World Health Organization (WHO). This definition only includes the polysaccharide components of plant cell walls. The European Food Safety Authority (EFSA) uses the term AOAC fibre for intake recommendations. AOAC refers to methods developed by the Association of Analytical Chemists to quantify total non-digestible polysaccharides including lignin and resistant starches. NOTE: AOAC essentially includes NSP but also any nondigestible carbohydrates that occur naturally in or are added to food (as ingredients) thus AOAC values are often higher than NSP equivalents which often results in variable reports of fibre content in the literature.

## Functionalised fibres

From a regulatory perspective, the key issue is whether functionalised fibres are approved as food ingredients or food additives, as different regulations/restrictions apply to the use of each. The regulatory environment also varies on a regional basis. It is the manufacturers responsibility to ensure that a fibre product has approval and the correct declaration for the intended end market. In June 2018, The [FDA](https://fdasimplified.com/blog/fda-updates-the-list-of-recognized-dietary-fibers/) published new guidance relating to dietary fibre. The guidance proposed that “mixed plant cell wall fibers” be added to the list of approved “dietary fibres”. Defined as ingredients that contain two or more of the following plant cell wall fibers in varying proportions: cellulose; pectin; lignin; beta-glucan; and arabinoxylan". The FDA recognises that mixed plant cell wall fibers can be obtained from food sources that have undergone other processing. Examples given included (not exclusive) - apple fibre, sugar beet fibre, potato fibre, oat hull fibre, pea fibre (hull and cotyledon), bamboo fibre and citrus fibre. The guidance also states the agency will exercise enforcement discretion which effectively allows immediate use of mixed plant cell wall fibers as dietary fibres in food and supplement products.

In Europe there are a number of things to consider: whether the fibre source material is considered a food or whether it falls under [Novel Foods Regulation (EU) 2015/228363](https://ec.europa.eu/food/safety/novel_food/legislation_en).; whether the processes used to manufacture the fibre are (a) approved, new or novel and (b) give rise to significant changes in the composition or structure of the food ingredient so as to affect nutritional value, metabolism or level of undesirable substances. Traditional fibres derived from fruit, vegetables and cereal sources are classed as food ingredients in Europe. Fruit and vegetable derived functionalised fibres that are currently in the market tend to have manufacturers recommended label declarations like “citrus fibre”, “dietary fibre”, “vegetable/fruit/cereal fibre” (depending on the source) or occasionally the term “flour” is used.

For fibres derived from non-food sources, like wood pulp, the labelling is generally powdered cellulose but functionalised products often contain Carboxymethyl cellulose (E-466) as a processing aid required for drying (e.g. SenseFi®).

## Seaweed

At present there is no harmonised regulation for the use of seaweed in human food and health & wellness products in Europe. [Barbier et al (2019)](http://www.phycomorph.org/pegasus-phycomorph-european-guidelines-for-a-sustainable-aquaculture-of-seaweeds) provide a recent summary and more detail can be found in Holdt & Kraan (2011)[[3]](#footnote-3). The French industry has issued its own guidelines and many other countries follow these although they are “guidelines” and not regulated by law. CEVA, France publish regular updates on the French & European [regulatory status](https://www.ceva-algues.com/en/document/edible-algae-regulatory-update/) on their website.

The sale and use of seaweeds and seaweed derived ingredients in Europe is regulated under [General Food Law (Regulation (EC) No 178/2002)62](https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32002R0178). “Seaweed” is recognised as a food in Europe under the CODEX classification system as a vegetable or processed vegetable: “Vegetables” = mushrooms and fungi, roots and tubers, pulses and legumes, and aloe vera, seaweed, and nut and seed purees and spreads and nuts and seeds. But note that the term “algae” does not come under this definition. At present, EU regulation is not consistent with use of terms algae, microalgae, macroalgae & seaweed.

Consumption of seaweed and seaweed derived ingredients is also covered by the [Novel Foods Regulation (EU) 2015/228363](https://ec.europa.eu/food/safety/novel_food/legislation_en). *Laminaria digitata, Saccharina latissima* and *Alaria esculenta* are listed as not novel in [The Novel Foods Catalogue](https://ec.europa.eu/food/safety/novel_food/catalogue_en) as all have a history of consumption in Europe prior to 15 May 1997 when the legislation was introduced. Note however, that under this legislation, *Saccharina latissima* is listed as *Laminaria saccharina*.

1. Gel strength - standard test method based on 1% (w/w) dispersion and reported at 1s-1 [↑](#footnote-ref-1)
2. Viscosity - standard test method using an internal set mechanism, adjusted for % dry matter. [↑](#footnote-ref-2)
3. Bioactive compounds in seaweed; functional food applications and legislation. Appl. Phycol. 23: 543-597 [↑](#footnote-ref-3)